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ASSESSMENT OF TECHNOLOGY FOR CLIMATE CHANGE ADAPTATION IN SUB-SAHARAN AFRICA

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The Sub-Saharan African economy depends on export to a large extent. For that reason, a shift in global commodity prices greatly affects the economies within the region. This is particularly true for countries whose GDP is greatly contributed to by Crude oil production, precious metal mining and crop production and export. Most people income depend on crop production that effected by climate change. Current social structure of agricultural communities has been influencing technology usages in Sub-Saharan Africa. Its influence on agricultural productivity shows potential of fast growth. Sub-Saharan Africa is trying to adopt new technologies. Technological outlook of the region however shows low technology adoption. International organizations have made effort in supporting new technology use in agriculture within the region. The world is moving towards intensive agricultural production characterised by high input use, specialisation in crops and animals, and postharvest technologies. New technologies should not cut down on employment in agriculture since the population is mainly employed in that sector. The objectives of this study are to assess the extent to which existing technologies have impacted the agricultural productivity of the region, and to identify some new technologies that are needed to complement or substitute the existing ones in order to achieve a robust adaptive capacity and reduce emission from the region.
Keywords: Need assessment, climate change adaptation, technology.

INTRODUCTION

The Sub-Saharan African economy depends on export to a large extent. For that reason, a shift in global commodity prices greatly affects the economies within the region. This is particularly true for countries whose GDP is greatly contributed to by Crude oil production, precious metal mining and cash crop production and export. Recent forecasts estimated stable prices for global commodities particularly oil and gas. It has however been indicated that there is a rebound in the region's economy, registering 2.5 % in 2017 from 1.3 % in 2016 (Kambou, 2018). This growth, as expected, was mainly due to recovery of commodity prices. Other favourable factors that contributed to this observation are the stability in inflation of commodity prices, reduces militant attacks and improvement in the performance of the agricultural sector (as a result of good rains in some part of the region). Current account deficits have improved especially in crude oil and precious metal producing economies with the region. Though the level of foreign exchange reserves within the region are still low, foreign direct investments are expected to improve within the coming years as investment in the hydrocarbon industry improves. Exchange rates of currencies within the region have stabilised recently and with increasing production of export commodities, improved prices of global commodity markets and the weakness of the dollar relative to other international currencies in recent years, the local economies witnessed an ease in exchange rate pressures. The economic growth of the region is therefore expected to rise up to 3.6 % by 2020 if commodity price stability is sustained and domestic demands are strengthened alongside stable inflation. Increased activities in the US and the European regions will further improve the economy of the region especially those countries with high income in export.

The risks to this progress are excessive external borrowing by central governments (which can worsen the interest rates thereby leading to economic instability), political and policy uncertainties (especially in countries such as South Africa, Zimbabwe and Togo), droughts (due to the changing climate: this may adversely affect the agricultural sector) and poor security situations (particularly in Central and West Africa: where the activities of the militant groups such as the Boko Haram has not been completely curtailed). The sub-Saharan African economy is seriously affected by external shocks as indicated above. The reason being the high dependence on raw material export, low export of manufactured goods, low intra-regional trade compared to that between Europe and the US, low export of service and similarity of trade structure (making them competitors for the same foreign market), making the region's economy responsive to external shocks (Smutka and Tomšík, 2011). With a stable commodity prices as forecasted and the increasing investment in infrastructure by some of countries within the region, significant growth can be expected. This growth will not come without some prior structural change in policy and technological investments.

Generally, it can be seen that the economy of the region depends on external support, thus, increasing impacts of climate change will worsen the dependency.

Current Social structure is influencing technology usage in Sub-Saharan Africa. Social structure of Sub-Saharan Africa and its influence on agricultural productivity shows potential of fast growth. The population of the Sub-Saharan African region has been indicated to be more pro-entrepreneurship characterised by its high small informal enterprises which for most of the population is a necessity due to low income even in formal sectors. Entrepreneurship is also seen as a source of status and a career of choice in the region (IMF 2017). This phenomenon can explain why agriculture employs a great potion of the population and is also dominated by peasants with small farm sizes. For this reason, some writers consider the rating of unemployment in the region as over rated as a great potion of the youth find themselves in the informal sector. The region is very young relative to other parts of the world. In fact, it has been identified as seven years younger than the second youngest region on earth: half of the population is made up of persons younger than eighteen, up to 30 % of the population is between 15 and 25 years and these numbers are not in any way expected to significantly change within the next few years (Smutka and Tomšík, 2011). The reason for the stability of the percentages being that, fertility rates are high, incomes are low and literacy is relatively low. Robust economic growth is not expected with these characteristics especially for countries which are not into crude oil or precious metal export. Majority of the youth, thus, are engaged in the informal sector which is less productive and small.

Need assessment of new technologies in agriculture for climate change adaptation is different in different locations of Sub-Saharan Africa due to the different focus on agricultural produce by different ethnic groups. The Sub-Saharan region is a home to multiple ethnic groups with diversity in culture. A unique identity of the ethnic groups however is their inward focus. It has been identified that ethnic groups within the region are more likely to undertake activities that directly benefit their members and further identify with a particular enterprise (Rivera-Santos *et al.,* 2015). Agriculture however is a common activity with most groups and various specialities influenced by geographical locations and culture. Cash crop production is common is this instance, particularly for regions where governmental incentives are available. Cocoa production can be cited as an example in this regard with regions in the southern part of Côte d'Ivoire, Ghana and Cameroon leading the production. Crude oil production and mineral mining are dominated by foreign companies which only need low skilled local labour to achieve their productivity. A 2017 publication by the Population Reference Bureau indicated that the Sub-Saharan region has low NEET (Not in Education, Employment or Training) rates due to the engagement of the mass of the population in low productive jobs (Kaneda and Dupuis, 2017). The female gender as usual is generally disadvantage in terms of education and income. The fragmentation of farm lands has been used as a major point in arguing against the possibility of intensive mechanisation of the Sub-Saharan African agriculture. This has also afforded more people (especially women) employment though the productivity is very low. As the population is increasing, agricultural productivity has to also increase alongside in order to meet the food demand of the increasing population. Generally, it can be said that the region has working population willing to work, particularly in enterprising, but there are no opportunities, thus forcing them into small less productive informal businesses. Technological needs, thus, will have to take account of all these factors.

Sub-Saharan Africa is trying to adopt new technologies. Technological outlook of the region however shows low technology adoption. The speed at which the world is moving with respect to technological advancement has never been seen in modern history. Same cannot be said of the Sub-Saharan African region as it has witnessed low technology adoption and creation particularly in the agricultural sector. General purpose technologies such as electricity and ICT have been instrumental in the development of developed part of the world but such cannot be said of the Sub-Saharan African region which has failed to benefit from the high positive impacts these technologies have to offer in economic development (Bayuo, 2017). Recent surveys have recorded increments in the usage of mobile communication devices within the region but subscriptions to a mobile network is below the world average.

International organizations have made effort in supporting new technology use in agriculture within the region. The world is moving towards intensive agricultural production characterised by high input use, specialisation in crops and animals, and postharvest technologies. The peasant nature of the region's agriculture has for a time not afforded itself to intensive mechanisation coupled with low research in agriculture specific to the region. This has made the region a net importer of technology and agricultural food products. Drought has been recognised as a threat to the agricultural sector of Sub-Saharan Africa due to the region's over reliance on rain-fed production which has been estimated to reach 70 % of the total production (Masinde, 2015). Development of irrigation and drought forecasting technologies has thus become very import. There are many technologies in the world today for high production in agriculture and food technology. The less usage of these technologies in the region has resulted in the low agricultural production. The region has potential for technological development and marketing. Governmental commitments have to create innovative atmosphere for young people followed by establishment of intra-regional knowledge sharing relation. This will be an effective way to catch-up with the rest of the world in terms of technological advancement.

New technology uses are not just economic need; it is ecological needs in Sub-Saharan Africa since the environment is relatively less polluted. Ecological condition of Sub-Saharan Africa still natural. Sub-Saharan African region emits the lowest greenhouse gas that has resulted in the recent anthropogenic changes seen in the climate pattern. This could be attributed to the low industrialisation of the region and limitation of the usage of energy production plants and advance transportation vehicles which emit a great potion of the GHG. Others have postulated that the reason for low emission from the region is the inefficiency in data collection and differences in results of climate models. With this less contribution to the emission data, the region suffers one of the worse impacts due to it ecological condition. It has been published that the agricultural system of the region contributes a great part of the region's emission of GHG (Kim *et al.*, 2016). This is expected due to high production of large ruminants, incidence of bushfires, slash and burn method of land preparation among other cultural practices. Sub-Saharan Africa has almost all its land within the tropical region, thus creating a warmer climate all year round with the exception of certain part of the southern region. The aridity index of the region is predominantly between 0.05 and 0.8 with very few regions recording above 1.2 (Trabucco and Zomer, 2014). It has been estimated that 43 % of the land surface is dry representing 70 % of agricultural lands, with increasing climate impacts, dryness is forecasted to increase by up to 20 % (Saghir, 2015). Decrease and irregularity of precipitations have already been reported by the IPCC. This condition makes the region very vulnerable to the impacts of climate change. No wonder migrations from the region is increasing though conflicts could also serve as contributory factors. Maize, millet, sorghum and cassava are the most common crops in the region and their production is expected to increase with the increasing climatic impacts due to their drought resistance and suitability for the soil conditions. In the worst scenario however, up to 30 % reduction is expected (Saghir, 2015) if no significant adaptive capacity is built within the shortest possible time, the impact of which will be very detrimental to life and property.

New technologies should not cut down on employment in agriculture since the population is mainly employed in that sector. The region is comprised of 23.29 million sq. km land and water surface (NationMaster, 2018) home to a 979.02 million individuals with a population growth rate of 2.76 % per annum and a total of 10.25 million sq. km of agricultural land (World Bank, 2018f). The population of sub-Saharan Africa is expected to hit 2.1 billion by 2050 with growth of Agriculture mostly propelled by expansion of cultivated area and intensification of cropping system though productivity per worker is less than the global average; for instance sub-Saharan African worker productivity is by 0.9 less in factor to the productivity of an Asian agricultural worker (OECD/FAO 2016). The expansion of cultivated area may not seem a major problem now since about 60 % of the world's uncultivated arable lands are in the region, but it will be recognised that it is not sustainable in the long run due to its propensity to degrade the land rendering it unproductive to posterity (World Bank, 2011). Agriculture is a leading employer of the region's population and contributes significantly to GDP, with a major potential to end the endemic poverty and malnutrition which have stricken the region for ages if well managed. Recent studies have shown that countries within the region are moving from net importing of food to self-sufficiency. Examples can be cited in Ghana, Nigeria, Tanzania, Zambia, Rwanda and Malawi who have implemented programmes in support of farmers and are significantly moving away from net food importation (World Bank, 2011). Sub-Saharan Africa is made up of majority small-holder farmers with fragmented lands. This has resulted in continuous cropping with no opportunity for fallow, with negligible land maintenance or amendment addition which recent publications recorded as causing serious land degradation leading to a lower productivity even with improved varieties released by crop breeders (OECD/FAO, 2016). Other factors causing the lower productivity of agriculture in the region are over-dependence on rain fed agriculture, low mechanisation and limited access to credit. As at 2009, only about 4 % of agricultural production is under irrigation though part of the region has capacity to establish renewable water sources (United Nations, 2009). The situation may be worse if not well managed due to the increasing population and the projections of possible harsh climatic conditions which will further put the sub-Saharan African agriculture into jeopardy. Most of sub-Saharan Africa rely heavily on cereals and root and tuber crops as staple food. Animal production is also common with cattle, sheep and goats leading the production as well as fish. Rice, maize, sorghum, millet are the predominant cereals consumed and cassava and yam follow as the most consumed staple crops in the region (Elbehri *et al.*, 2013). The region has potential for increasing productivity if efforts are put in place to ensure that infrastructure, energy supply and R&D are improved with significant reduction in corruption (Elbehri *et al.*, 2013). With the projected climate change impact, similar policies and practices that are working well for the export commodities such as cocoa and fruit crops must be established to improve the productivity of the stable crops. For instance, 66 % of the world cocoa production is from sub-Saharan African countries with an annual growth rate of 2.7 as against 2.2 for the rest of the world (CBI Market Intelligence, 2016). This performance is even projected to be lower than the capacity of the region to produce cocoa. It is thus evident that if much effort is put in the production of the region's staple crops, the envisaged hunger due to climate change and population increment will be contained. The surest way to achieve that is by investing in new technologies and effectively managing the existing ones.

The objectives of this study are to assess the extent to which existing technologies have impacted the agricultural productivity of the region, and to identify some new technologies that are needed to complement or substitute the existing ones in order to achieve a robust adaptive capacity and reduce emission from the region. The questions that this paper seeks to explore are; by how far have these strategies been implemented in these sub-Saharan African countries? How has been the acceptance by farmers and other beneficiaries? What are the matters arising from their implementations? What are the new technologies relevant to building the agricultural sector? The PESTEL model uses for analysing the level of demand for new technologies in dealing with climate change. The model has the potential of creating a bigger picture of the pressing needs of an entity. It renders itself easier to understand by readers and also provides the bases for further research opportunities. The PESTEL model stands for P-Political, E-Economic, S-Social, T-Technological, E-Ecological and L-Legal. The various factors considered in the model gives it the broad view it possesses. The paper looked at the economic, social, technological and ecological outlook of the sub-Saharan African region as factors influencing agriculture and the building of adaptive capacity to climate change, after which, make a policy and legal recommendations that are relevant in strengthening the regional agriculture. Technologies suggested within this paper will be of diverse origin hence may demand some level of modification to suit local needs.

LITERATURE REVIEW

Technological inventions of any kind have undoubtedly change the scope of our lives and the lives of other organisms within our ecosystem. Doing away with the negative consequences of technology, we can say that technology has improved our activities with effectiveness and efficiency amidst real time result. The use of technology has helped achieved tasks that sole efforts of humans are incapable. In fact, technological advancement has significantly increase the performance of humans in many fronts (Imran *et al.*, 2014). It is on this background that technologist and modern researchers advocate for the adoption of modern technology in the verge to combat the impact of the menace posed by climate change on agriculture and other fields of human endeavour.

Africa has been identified to be one of the regions to be hit harder by the impacts of climate change due to increasing vulnerability as a result of low adaptive capacity which has been brought about by several factors including poverty (Housseini and Alkire, 2014) and over dependence on natural resources, complex governance and institutions, low level of technology and limited national infrastructure (Boko *et al.*, 2008). Several least developed countries are running programmes for assessment of vulnerability levels and adaptation needs in order to develop national adaptation programmes and plans (National TNA Project, 2013). Amongst the three main outcomes of the Paris agreement, parties have agreed to make financial commitment to the course of climate change with special interest in supporting underdeveloped countries and countries most vulnerable to the impacts of climate change. The other two are to; 1) reduce the global temperature rise below 2 °C above pre-industrial levels and to make efforts to limit it to 1.5 °C within this century and 2) increase the ability for adaptation and resilience to the impacts of climate change alongside reducing the emission of greenhouse gasses (UNFCCC. Conference of the Parties (COP) 2015). This agreement which some commentators referred to as over ambitious will in fact cushion the financial burden of least developed countries in their pursuit to build capacity for adaptation to the increasing impacts of climate change.

Technological strategies that farmers are employing in sub-Saharan Africa in their effort to adapt to the changing climate include the use of drought resistant crop varieties, improved tillage and irrigation for water and soil conservation, and the intensification of agro-forestry and afforestation (Akinnagbe and Irohibe, 2014). Other strategies include the rearing of cross-bred animals, keeping smaller animal, instituting a rapid response team for outbreaks of diseases and other extreme situations (Nzuma *et al.*, 2010) alongside governmental policies. These strategies if well implemented and managed, stand a great opportunity to build an effective capacity for adopting countries to adapt to the impact of the changing climate.

Economic activities in the region are dominated by the informal economic sector, earning between 25-65 % of GDP which represents 30-90 % of non-agricultural employment activities (IMF, 2017). The rate of informality is particularly high with lower incomes and unemployment in the formal sector. It has been recognized by economic researches that the informal sector reduces in size as incomes increase within a region. The Sub-Saharan African region is currently leading the rate of informality in national economics second only to Latin America. Economic analysis by the IMF indicated that oil exporting countries are most likely to indulge in negative forms of informal activities in the economy such as tax evasion. Unemployment has also been identified as a leading cause of rise in the informal sectors of the economy, serving as safety net for large part of the population which have either moved to the urban centres where agricultural activities are low or people who had no opportunity of joining any formal sector due to insufficient vacancy as a result of low employment creation by central governments. The problem with the informal sector is it low productivity compared to the formal sector. On average, it has been estimated that the productivity of the informal sector is only 25 and 19 % of a small and medium sized formal sectors respectively (IMF, 2017). In countries such as Kenya, Namibia, Niger, Senegal

and Tanzania, the gap between the formal and the informal sector are particularly very high. The reason for their low productivity can be attributed to their relatively small sizes, lack of credit to grow, low technology usage and high focus on the development of the formal sector by the governing institutions. High taxation has also been identified as leading to informality even with formal sector. It has been suggested that increasing the size of formal sectors to create employment will reduce the size of the informal sector. Also, supporting the growth of the informal sector (by making credit available, providing training and easing the formalisation process) will make them big enough to grow into other formal sector there by increasing their productivity.

***Climate Change And Its Impacts In Sub-Saharan Africa*:** As a result of different outcomes recorded by models used in the forecast of the region's climate, there is no absolution when it come to the impacts. Generally, it is agreed that the sub-Saharan African sub-continent will receive variable impacts over the coming years. Whilst some countries will be experiencing significant reduction in the amount of rain and its regularity, other countries will receive an increment in the amount of rainfall. Temperature however is expected to rise across the region which will lead to significant climatic impacts especially on agriculture as the region's agriculture depends largely on rainfall. It has been estimated that the arid and semi-arid areas of the region are likely to increase by 5 to 8 % (about 60 to 90 million hectares of land) by 2080 with a reduction in crop growth periods and yield (some regions will experience up to 50 % yield reduction with current agricultural practices) (Boko *et al.,* 2008). These observations are consistent with the publication of the IPCC in which it was stated that 0.5 °C or more was the temperature increment observed over the last 50 to 100 years
(Niang *et al.,* 2014). The projections are also consistent when it comes to temperature increases and variability in precipitation. Aridity and semi-aridity were thought to be caused additionally by changes in anthropological use of land and land resources. Sea-level rise are also projected to be higher than the global average by 10 % (Serdeczny *et al.,* 2016) which will further reduce the amount of cultivable land for arable crops due to salinity and relocation.

The emission data continuously shows a significant difference between per capita emission of sub-Saharan Africa with the rest of the world. Whilst North America records the highest of 19.36 to 16.35 metric tons per capita between the years 2005 and 2014, sub-Saharan Africa within the same period recorded 0.87 to 0.84 metric tons per capita, most of the rest of the world hovered around 6.5 metric tons per capita as at 2014 with the world average being 4.97, a slight increment from the 2005 figure of 4.52 (World Bank, 2018c). A great amount of GHG emission from sub-Saharan Africa comes from agriculture as a result of land use and management practices (Kim *et al.,*2016). Recent research has indicated that there exists a gap in the amount of data on emission which may also explain the consistent low output of the region. Both emission data and models to accurately forecast the climate of the region are an important issue that must be looked at in order to be able to tackle the impacts on the region effectively. Generally, however, it can be said that sub-Saharan African emits lesser amount of GHG as compared to the developed regions of the world due to it low industrialisation.

Ironically, the sub-Saharan African region is still forecasted to be the region to receive most of the impacts of the changing climate due to its low adaptive capacity. It has been argued that the cost of building adaptive capacity should be footed by the developed countries for the reason that they contribute much in emission and are better resourced to do so (Morris, 2013, Barrett, 2007). The burden on the bearing of the cost of capacity building for climate change is not a major problem so-far-as parties to the Paris Agreement keep to their promise and developing nations such as those in sub-Saharan Africa take initiatives in building local capacity through policies and practice.

Climate change has also been projected to have an enormous impact on health and security of humans, plants and animals. With increasing temperatures, there is bound to be increase in heat related conditions such as heat exhaustion, heat stroke and death at extreme cases in both humans and animals alongside a marked reduction in productivity beyond the biological threshold. Death as a result of increment in environmental temperature has been reported in medical publication; for instant in Ghana (Azongo *et al.,*2012). Increasing temperature calls for increasing demand for water to cool biological systems. With a projected reduction in rainfall and water availability in some part of the region, there is likely going to be high reports of fatality especially in areas with very low adaptive capacity. Reduced water availability is going to lead to the usage of poor quality water predominantly in rural areas which will lead to the wide spread of water-borne diseases in affected areas coupled with malnutrition as a result of low production. Those parts of the region projected to receive increment in rainfall by some temperature models will face the risk of flooding which is a sure way to transfer pathogenic agents to different locations within the region. It is clear at this point that human and agricultural health will be negatively affected by the projected changes in temperature and precipitation if structures are not put in place to contain them. With increasing low productivity of agriculture within the region, food insecurity will be in the rise, leading to increasing costs of food for even the middle-class. Poverty, thus, will be in the rise, leading to communal conflicts and possibly civil conflicts which have been postulated to escalate with increasing environmental temperatures (Serdeczny *et al*., 2016).

Demands for energy is going to increase with the changing climate. Currently, households use electric energy for cooling especially in the hotter periods of the dry seasons. Crude oil is mostly used in agriculture and industrial production. With

increasing concerns on their impact on the climate, alternative renewable sources of energy are needed not only for the production sectors but also for household use. Nuclear energy despites the security concerns have been identified as an effective source of energy to offset the growing demand. Other popular sources include solar, wind, hydro and biofuels. There are advanced technologies today in the world for all these options that sub-Saharan African countries can take advantage of going forward.

All these observed changes, projected changes and forecasted impacts can be mitigated by the effective use of technology to build efficient adaptive capacity. Agriculture, haven't been identified as a strong contributor of the region's development, alongside governmental efforts to achieve food security, are obviously important factors that should move the advancement of strategies to improve the region's economy. The agricultural systems of the food self-sufficient countries outside the region are operated under improved and well managed agricultural technologies that undergo constant improvements to face new challenges. Thus, the way forward is to adopt strategies that will include technologies easy to implement and manage by the region's farmers. Most of the countries in the region have developed plans individually or in collaboration with other neighbouring countries to implement technologies in their agricultural systems in order to adapt to the changing climate (Nzuma *et al.,* 2010, National TNA Project, 2013). The situation in sub-Saharan Africa is not all gloomy as there has been a lot of success stories. The activities of governments, international bodies and NGOs towards building resilience and capacity are receiving some public support. The last IPCC report indicated a potential reclamation of degraded agricultural lands through the planting of trees which in some cases are nitrogen fixing, the systematic increment of species and density of trees within some regions, introduction and use of some technologies for energy creation and utilization alongside improved farming methods (Niang *et al.,* 2014).

***Current Assessment of Crop Production Technologies*:** Since the farmers of the sub-Saharan African region are predominantly peasant, it is expected that a great portion of the interventions to address their pressing needs should come in forms such as availability of seeds of good quality, water management and availability, soil management and amendment, and good agricultural practices that will result in making efficient use of the fragmented land resource available to the farmer. In the TNA of the Sudan, much attention was given to improving the activities of the peasant farmer without necessarily including mechanisation. Again, In the ASARECA Member Countries' discussion paper, it is clear that much attention has not been given to mechanisation. The priorities were on introduction of improved varieties of crops and moving towards zero/minimum tillage (Nzuma *et al.,*2010, National TNA Project, 2013). These are in line with the strategies within the NASPA document of the Republic of Nigeria and other publications (Creech *et al.,*2012, BNRCC, 2011). It must be pointed out however that intensive agriculture that has resulted in higher productivity has often used mechanisation as a driving force in production. The major problem with mechanisation in the sub-Saharan African region is the fragmentation of the land system.

Over the year the major cultivar research institutions working in the region (IRRI, CIAT, CIRAD and IITA and others) and other international and academic research centres have released cultivars that have in some ways better the performance of the agricultural sector of the region. Maize, millet, sorghum, cassava, yam, rice and other staple crops led the majority of the released crop varieties (The National Academy of Sciences, 2008). The major traits of these varieties were drought resistance, early maturing, ease of management, disease and pest resistance, and high quality of certain nutrients (Creech *et al.,* 2012, Ahmed *et al.,* 2000). These strategies are in line with the climate impacts envisaged and thus appropriate for the region. Very large amount of new cultivars has constantly been released in the market for farmers to take advantage of in order to improve their farm productivity. For instance out of the about 500 cultivars of maize cultivated in the region in the 2013/2014 growing season, 54.2 % were product of research which have penetrated across the region in varied acceptability (Abate *et al.,*2017). As early as 1996, 40 and 16 sorghum and millet varieties have been released respectively in the region (Ahmed *et al.,* 2000). More cultivars are constantly being released though the annual yield does not reflect the effort of breeders in a favourable manner. It is a fact that from the year 2000 to date, more than 20 % of the world's total agricultural lands are in the sub-Saharan African region, ironically, cereal production in the region hardly go beyond 150 million metric tonnes out of the 2.8 billion metric tonnes of production over the years, though Europe and the North America covering only about 16 % and 9 % respectively constantly produce more than 550 million metric tonnes and 480 metric tonnes respectively (World Bank 2018a, 2018b). This result was achieved though there exist significant amount of research and adoption of improved cultivars of cereal across the region, with maize reported to record more than 50 % adoption across the region (Abate *et al.,* 2017).

Sub-Saharan African researchers have attributed the poor performance of the agricultural sector to several reason including degraded lands, poor water management systems, poor information flow due to inefficient extension service, insufficient financing for farmers and researchers among others (The National Academy of Sciences, 2008). It is obvious that most peasant farmers have no access to the modern technologies thereby make less use of them. The data indicated that a lot of farmers keep their seed, cultivate on the same land over years with little soil fertilization and close to no irrigation (World Bank 2018e, Abate *et al.,* 2017). As already mentioned, the mechanisation level of the region's

agriculture is very low making it a contributory factor in the low productivity. Until recent years, most peasant farmers use hand tools or at best animal power in cultivation. Efforts made to introduce farm machines into the system have proven futile due to the fragmentation of the production lands. There has been little improvement in recent years as a result of the importation of some small machines from the Asian continent (Fatunbi and Odogola, 2018).

It can be said at this point that not much technology has entered into the sub-Saharan African region as compared with the rest of the world. The amount of technology introduced in the region has not received total patronage due to several reasons including insufficient extension service, lack of access, low financial support among others. The sub-Saharan African agricultural sector therefore needs conscious effort at improvement to meet the world standard owing to the increasing population and negative climatic impacts. This is to ensure that, much food is produced to the level of self-sufficiency, which will thus propel the development of the predominantly agrarian economy. Without these developments, food security will be difficult to achieve in the region and consequently national security will be difficult to keep as inflation will go high resulting in low access to food and heightened poverty (some of the factors which lead to instability of a nation.

***Current Assessment of Animal Production Technologies*:** The major animals raised in the sub-Saharan African region are cattle, sheep, goats, poultry and pigs. Fish is also an important source of protein in the region alongside other animals often referred to as non-traditional animals which include grass-cutters, rabbits, guinea fowls and others. This paper will concentrate on the major animals including fish since that provide majority of food and its data easily comparable with other regions of the world. As at the year 2015, the population of cattle across Africa, sheep, goats, pigs and poultry number 310 million, 360 million, 340 million, 34 million and 1.9 billion respectively (Mwai and Ojango, 2016). Most of these animals are kept not for the sole production of food but other purposes such as safety net during times of crisis, collateral for credit, store of wealth among others (FAO, 2018). The primary product that farmer derive from these animals are meat, milk, eggs and leather. The productivity of these products are not anywhere near their demand particularly poultry and milk.

There is bound to be great changes in the production and consumptions trends of animal products in the sub-Saharan African region owing to the projected increase in population and urbanisation. The impact of climate change is another major factor that will direct the course of production and consumption of animals and animal products. It is estimated that consumption of milk will triple whilst meat from mono-gastric animals (mostly poultry) will increase between four and seven across the region (Herrero *et al.*, 2014). Recent statistics show that milk production in the region stands at an average of 1.5 kg/cow/day whereas in the USA, the production is at an average of 28 kg/cow/day and egg production with the highest in Ethiopia averaged 72 eggs/hen/year whereas the global average stands at 185 eggs/hen/year (National Agricultural Statistics Service, 2017, Compassion in the World Farming 2013, Mwai and Ojango, 2016). These data indicated that productivity is far behind compared with other regions of the world though consumption is increasing and demand is projected to increase in manifolds.

Not much has been promoted in terms of technology for animal production in the TNAs across the region for the reason that much of the food comes from crops and the system of animal production is not easily managed. Some of the technologies that can be found in the TNAs include improvement of rangelands and promotion of along river grazing, promotion of research into drought resistant animals and feed, enhancement of artisanal fisheries and sustainable aquaculture, promotion of keeping smaller animals and change of farming systems (Nzuma *et al.,* 2010, National TNA Project, 2013, BNRCC, 2011). Clearly, the technology that is workable is the breeding of new animals that will be adaptable to the changing climate and the provision of water sources for pastoralists in order to limit the altercations between pastoralists and crop farmers. Not much can be done in terms of technology to change the rearing systems of the ruminant breed of livestock. It is prudent then that governments and researchers in the development of TNA concentrate much on the development of new breeds to fit the changing climate.

Over the years, improved cattle breeds have been introduced into the region by breeding associations and research groups. Examples of those cattle include the N'Dama of West-Africa, Boran and Ankole cattle of Eastern Africa and Nguni cattle of Southern Africa. With these breeds and some lot others, there exist superior traits for good beef cattle breeding and production capacity which has not been taken advantage of (Strydom, 2008) for the reason that strategic breeding plans for genetic improvement are rare in the region, hence, there is a general lack of reliable sources of breeding stock and the stock available is of variable quality due to the presence of a variety of production systems for beef cattle, thus, strategies must be put forward especially in the national or regional TNAs if the benefit from available animal breeding technologies is to be utilized (Rewe *et al.,* 2009). It is evident that, not much has been achieved in terms of improvement in the area of breeding of ruminants in the region especially cattle though there exist enough genepool (Mwai *et al.,* 2015). Milk productivity of the animals in the region is very low. Research however is not in its advance stages to improve the dairy sector of animal production. Another important factor that has impeded the progress of the region's animal production is the level of adoption of new breeds of some

animals along with new technologies introduced to improve the diary sector as is the case in Ethiopia (Ergano, 2017).

The animal rearing system of sub-Saharan Africa with the exception of poultry is predominantly pastoral or mixed farming system with most of the poultry kept in the intensive system for commercial purposes (Magnusson, 2016). The pastoral system of animal rearing remains dominant amongst the Fulani, Maasai and the Tuaregs communities who hold majority of the cattle in the region (Mwai *et al.,* 2015). There is however a recent proliferation of intensive system of poultry rearing as a result of increasing demand and profitability, and as more international agribusiness players come into the region alongside increasing availability of vaccines to common poultry diseases. This development has not affected the totality of the population since there is an observed low adoption. The cause of low adoption was attributed to low access to capital, high mortality rate of new breeds, low skill of human resource and ineffective governmental policies (Heise *et al*., 2015). Aquaponics is another technology that will be very suitable to the region and has great potential for the future of the region due to its high yielding, economy of water and temperature demand (Goddek *et al.*,2015). There are pockets of investments in that regard but commercialisation has not taken a serious effect yet.

With the current trend of increasing demand for poultry, meat, milk and eggs alongside unfolding climatic impacts, it is prudent that governments actively work on the issue of adoption of technology and create policies to facilitate easy access to credit. There is also a general lack of animal breeds to fit the expected climate in the nearest future particularly in the area of milk and egg production. Generally, adoption of technology is a major problem in the region for animal production followed by low research and support by governments.

***Current Assessment of Food Processing Technologies*:** Food losses from production through to consumption has been estimated to be 15 % of the total agricultural production in the developing regions of the world with sub-Saharan Africa leading the chart (The Rockefeller Foundation, 2015). Postharvest losses have been identified as one of the region's impediment for food security (The National Academy of Sciences, 2008). This calls for concern as population is drastically increasing amidst a stagnant agricultural sector with an increasing concern on the strong impact of climate change. International trade of agricultural products from the region is largely dominated by the export of primary products or products with little processing (Mmaduabuchukwu, 2013). West Africa is undoubtedly the world's leading exporter of cocoa; about 85 % of the cocoa beans imports into Europe comes from West Africa, with Europe being the world's leading grinder and processor of cocoa (CBI Market Intelligence, 2016). It is further indicated that grinding of cocoa beans in the region is seeing a recent boost, however, most of these processing companies are owned by westerners. Very few countries have stated agricultural processing and postharvest technology as priority in their TNA. Those that have stated it or working on it are much concentrated on reducing losses from production and techniques for storage against pests and diseases and to take advantage of improved markets (BNRCC, 2011, Ministry of Natural Resources, 2012, Nzuma *et al.*, 2010). Some countries are resorting to the establishment of drying and storage facilities for resource-poor farming communities. The structures if well-established stand greater chance of helping farmers adapt to increasing threat of pests and diseases due to climate change. This is in fact not out of place since the aim of the region's agricultural sector is to achieve food self-sufficiency and not primarily to export processed foods. Rwanda has taken the lead in this regard with the establishment of storage facilities across the country for resource-poor farmers which is expected to cover about 1,400,000 households (Ministry of Natural Resources, 2012). The introduction of the Purdue Improved Crop Storage (PICS) bags in West Africa has received several scientific and farmer support in its ability to maintain grain quality over eight months period (Williams *et al.,* 2017, Baoua *et al.,* 2018). Apart from maintaining quality of storage products, the bags are able to limit insect infestation. The most important condition for the bags to work well is achieving a certain moisture content before storage. The absence of improved drying facilities, access to credit and lack of information to some group of farmers may account for the lower patronage of the bags. In Ghana, an association of peasant farmers with sponsorship from the Netherlands Development Organisation, are advocating for policy improvement towards reduction of post-harvest losses by supporting the adoption of modern technologies (Baafi, 2017).

With the growing population and urbanisation, demand for processed foods are bound to increase hence policy makers and business players must direct some of their energy toward that direction. New processing factories are being erected across the region in recent times to take advantage of the increasing demand and as a measure for the impact of climate. Ghana for instance has in recent years gone forward with the construction of factories for the processing of sugar cane, cocoa, maize and in this year cassava (Frempon-Ntiamoah, 2018). There exist similar developments all across the sub-Saharan African region to boost the capacity for food security and economic advantage.

***Current Assessment of Energy Sources*:** Energy is an important field in the discussion of climate change whether causes, adaptation or mitigation in that, it is the driving force of all economies and livelihood today. Sub-Saharan Africa is not generally a net energy importer due to the low energy usage in the region. On kilogram oil equivalent, the per capita usage of energy in the sub-Saharan African region stands at 682.89 kg whilst the world average is 1,919.36 kg with that of North America being 6,878.56 kg (World Bank, 2018d).

The highly industrialised nature of the developed world compared to sub-Saharan Africa may account for the high per capita energy usage relative to the region. Hydroelectric energy account for about 21.17 % of the energy production of the region according to the World Bank report. This may not be sustainable owing to the increasing threat of climate change on water availability.

It is quite interesting to note that about 63 % of the population in the region currently live in rural areas with a lot having no access to electricity due to the high cost of connecting to the national grid, which however could be solved if off-grid installations are established for communities (Hancock, 2015). This method can be a sure solution for most of the countries within the region with very low connectivity and distant from the national grid. Governments across the region have taken steps in establishing renewable sources of energy particularly solar as irradiation is in abundance in sub-Saharan Africa (Mohammed *et al.*, 2013). Since 2010, an off-grid hydropower plant established for a Tanzanian community is helping in the community development which is a primary source of capacity building towards adaptation to climate change (Ahlborg and Sjöstedt, 2015). Another renewable energy plant in the region is a biomass gasification system established in the Tiribogo community of Uganda which has started providing sustainable energy to farmers who supply the plant with crop residue (Eder *et al.*, 2015). In Ghana, the story is not different in that the country currently generates between 1340 and 1820 MW of renewable energy and has an Act of parliament to make 10 % of electricity generation from renewable sources by 2020 (Asumadu-sarkodie and Owusu, 2016). This step is a major boost not only in extending access to electricity but also addressing the issue of climate change as it will significantly reduce emission and will build an adaptive capacity for vulnerable communities.

There still exists low coverage for energy especially in rural communities within the region due to some pertinent issues. Some of these issues include low income that leads to lower adoption, insufficient sponsorship for the high cost of installations, social factors that make off-grids unsustainable among others (Hancock, 2015, Ahlborg and Sjöstedt, 2015, Mohammed *et al.*, 2013, Eder *et al.*, 2015). Governments and NGOs have a lot to do in terms of sourcing for funding towards improving the level of access to electricity be it through the national grid or off-grid mini-installations. It is quite clear that access to energy boosts economic activities and has the potential to reduce poverty which in itself is a means of building adaptive capacity towards the forecasted impacts of the changing climate. It is however satisfying to realised that most of the TNAs of the region have strongly included the establishment of sustainable energy source in order to reduce vulnerability to climate change impacts and to boost economic activities thereby reducing suffering as a result of poverty (Nzuma *et al.*, 2010, Ministry of Natural Resources, 2012, BNRCC, 2011).

***Technology Need For Climate Change Adaptation*:** Technologies for adaptation to the impacts of climate change are the most important for the Sub-Saharan African Farmers. These technologies can come in different forms with focus on specific climatic impact. For instance:

***Drought management*:** advance technologies in drip irrigation could be introduce (similar to that of the Mexican farmers (UNFCCC, 2006) in Sosa, Oaxaca Valley) or new verities of crops particularly cereals and root/tuber crops be released to farmers. Irrigation could be limited to peaks of growth season for which technologies are available to determining the timing.

***Soil Management*:** the threat to the soil of the region among other factors include nutrient depletion, erosion and soil preparation. Maintenance of grass waterways, roughening plant growth beds, minimum/zero tillage, mulching, fertilizer application technologies should be introduced and ultimately conservation agricultural technique integrated soil fertility management and site-specific nutrient management (Dinesh and Vermeulen, 2016).

***Increase yield of crops*:** increased yield is a factor of genetic resource and environmental condition. Most locally existing varieties need improvement. There has been an advancement in the area of biotechnology and gene transfer. These technologies can support the development of new varieties that are high yielding and adaptive to the local climatic conditions. Some of these crops can be found in table 3 below. Farmers have to diversify crops on a field and intensify amount of plants in on land (an example is situation in Vietnam, Burundi, Rwanda and Uganda (Dinesh and Vermeulen, 2016)).

Farm energy sources: there are modern development in tapping energies from wind, water and solar. These systems could be established off the grid for communities difficult to connect to the main grid. There are mini-plants which can even support individual farmers. Examples can be cited in the BIRU and SPaRC projects in Indonesia and India for bio and solar energy respectively (Dinesh and Vermeulen, 2016).

Mechanisation: agricultural mechanisation is very important in its efficiency and effectiveness. Most farmers use tractors just for ploughing their lands. With appropriate implements, most of the cultural practices can be done effectively with the tractor. There are mini-cultivators which are less expensive and farmers can easily operate them.

***Information systems*:** technologies are advance in the area of information and communication. With the increasing number of people using mobile phones in Sub-Saharan Africa, applications can be developed to aid farmers manage their farm business efficiently. Weather reports can be transmitted through the application, resource availability can be communicated to farmers, training of farmers can be held online, farmers can report cases and other functions can be

achieved using the mobile phone. With the introduction of drones and robots, precision agriculture can be practiced.

***Knowledge management*:** there should be a system for integration of indigenous knowledge with modern technology. This will facilitate ease of adoption of new technology. This system

***Credit creation*:** There are various financial management strategies to support farmers with credit. Lack of credit has been identified as a cause of low adoption of some technologies. With availability of credit and subsidies for farm inputs, farmers will have the power to produce enough to sustain the population. Agricultural insurance should also be promoted in its different forms (examples include the ACRE scheme and R4 Rural Resilience Initiative in Western, Eastern and Southern Africa)

***Postharvest technologies*:** postharvest loss has been a major problem in the region. Seasons when high yields are recorded are not benefited from due to losses after harvesting. For most crops provision of farmer-scale postharvest systems will be a great aid to reduce the losses. On-farm shades, plastic crates, system for on-farm packaging, zero-energy cooling chambers, solar dryers, simple food processing technologies (Kitinoja, 2013) among others should be introduced.

***Conclusion*:** From the Rio Summit through to the Paris Agreement, governments in the sub-Saharan African region have participated and have developed documents with policies towards curbing the impacts envisaged to befall the region due to the high level of vulnerability as a result of poor development. Ranging from TNAs to NCCAP have been documented and are in constant contact with the UNFCCC and other United Nations' instituted bodies discussing way forward on climate change in the region. We can review some of the national documents to appreciate the amount of policy tools available within the region regarding climate action.

Nigeria recognised as the biggest in terms of population and economy in 2011 published her National Adaptation Strategy and Plan of Action on Climate Change for Nigeria (NASPA-CCN) in which there was systematic study of the trends and impacts of climate change, and a well stipulated policies and implementation strategies on sectors ranging from Agriculture, Energy to Capacity Building in vulnerable communities (BNRCC, 2011). Another example is the TNA report of the Republic of Rwanda which has embedded strongly in her vision 2020 policies, the need to protect the environment within the framework of developing and transferring technology in order to increase adaptive capacity to the increasing impacts of climate change (Ministry of Natural Resources, 2012). Among the French speaking countries of the region, we can cite the case of Burkina Faso's National Climate Change Adaptation Plan which has the objective of building resilience and adaptive capacity between its implementation up to 2050 in the areas of Agriculture, Energy, Infrastructure, Health and other economic and social development sectors (Ministry of Environment and Fishery Resources, 2015). The recent document is that of the National Climate Change Adaptation Strategy of the Republic of South Africa published as a second draft with the vision of transitioning the country into a climate-resilient one capable of anticipating, adapting and recovering through resourcing national adaptation needs and development of monitoring and evaluation system capable of tracking climatic changes (Ministry of Environment and Fishery Resources, 2015). There is a barrage of documents when it comes to plans, policies and strategies for implementation of climate change adaptation programmes within the sub-Saharan African region. Acts of parliament have been passed and national and international specialists have been put to work in assessing and recommending actions to be taken in the effort to contain the impacts of the change.

The existence of sub-regional bodies in the fight towards reducing vulnerability and increasing resilience cannot be over emphasized. The African Union has in fact made climate change adaptation a priority with plans to include the topic in its programmes, policies and activities. All the sub-Regional bodies have plans in supporting the development of strategies and policies to increase adaptive capacities towards climate change such as that by the ECOWAS (USAID, 2011). The challenges faced by these bodies and the national include among other issues implementation constraints due to low resource availability, low inclusion of realities of political and institutional factors, low participation of populace in the risk assessment and strategy development (Niang *et al.*, 2014).

There isn't great lack of policy in the region to tackle the menace of climate change following the publications of several national and regional strategic plans and policy. The international community has also sought to support these programmes by funding them and also providing technical support. It is however very difficult to admit that not much has been achieved in terms of adaptive capacity development due to low adoption of technologies and unconducive atmosphere for research and innovation. Other major barriers impeding the technological advancement of the region are low intra-regional knowledge development and transfer, poor technology management systems, relatively higher poverty and illiteracy, and over emphasis on traditional production methods (such as 'tractorisation' instead of mechanisation).

Government policies should thus focus primarily on the following:

i. creating conducive atmosphere for research and technology development
ii. establishment of technology management system
iii. easing of adoption of new technology which are user friendly
iv. establishment of intra-regional knowledge sharing and technology marketing systems
v. increasing technology adoption by reducing cultural barriers

The national and regional strategic plans reviewed above captured most of the points raised above. What is lacking is the creation of an atmosphere for innovation by the youth in the informal sectors which form a great part of the employment creation body. Through these policies, governments can promote the development of the informal sector by increasing their size and improving their technological bases. A more productive informal enterprise gradually develops into a formal sector and thus increase the income of the state.

Electricity is a major factor for improving productivity in agriculture and agribusiness. There should be policy to lower tariffs for the use of electricity from the main grid and establishment and usage of modern renewable sources. Irrigation is one of the major blockage to the progress of the region agricultural system. There should be policies for the establishment of irrigation facilities to cater for drought and irregularity in rainfall patterns.

Policies should be established to give incentives and credit to farmers who produce certain crops especially that which have high demand in the region. Research as well should be promoted through funding by government and the result be communicated effectively to all stakeholders. There should be revival and redesign of the extension service of the region to take advantage of modern communication tools and systems. The policies should promote farmer perspective in the technology design to facilitate adoption.

***Legal Recommendations to Back the Policy Recommendation*:** There isn't going to be an effective policy implementation without serious legal backing. The policies proposed in national or regional strategic plans should have laws or Acts of parliaments enforcing them. It has been established that most of the national or regional policy documents were created following the enactment of Acts of parliament. These legal tools should greatly follow the international regulations. Legal instruments should tackle the issue of emission by prohibiting bushfires, reducing the use of crude oil based energy, create termly policies to reduce emission, establish a national or regional panel for monitoring climate. On adaptation and resilience, legal instruments should be enacted to govern the use of land, breeding programmes that will disadvantage the peasant should be discouraged.

Information and communication technology education should be enforced in basic schools. This will ensure that young people leaving school are ICT literate thus any subsequent policy that will be implemented will be easily operationalised. Tariffs can be managed to allow the inflow of foreign companies to establish technology development institution in the region. There should by this be the review of the procedure for the establishment of new businesses especially for technology institutions. Mobile communication networks should be managed to lower rates such that peasant farmers can use the service especially for transfer and reception of information relevant to climate change.

The sub-Saharan African region is an area that is faced by increasing vulnerability to climate change amidst the proliferation of technologies for adaptation and building resilience. The situation is so due to several reasons including low R&D, low adoption of technology and the unending poverty situation of the region. It could clearly be seen in the agricultural sector where productivity has been very low especially for cereals, milk and eggs due to lower level of R&D in the system as indicated in the case of maize by (Abate *et al.,* 2017). Lower adoption of technology has been attributed to lack of effective extension service to disseminate information to targeted farmers as related by researcher in the (The National Academy of Sciences, 2008) publication. Low adoption can as well be attributed to poverty and insufficient credit for targeted farmers as in the case of the Ugandan community (Eder *et al.,* 2015). The situation is not overall very bad as governments, regional unions, international bodies and NGOs are taking actions at addressing the situation. There must however be a revolutionary action to salvage the region from the forecasted impacts of climate change.

REFERENCES

Abate, T., M. Fisher, T. Abdoulaye, G.T. Kassie, R. Lunduka, P. Marenya, and W. Asnake. 2017. Characteristics of maize cultivars in Africa: How modern are they and how many do smallholder farmers grow? Agric. Food Secur. 6:1–17.

Ahlborg, H. and M. Sjöstedt. 2015. Small-scale hydropower in Africa: Socio-technical designs for renewable energy in Tanzanian Villages Energy Res. Soc. Sci. 5:20–33 Online: http://dx.doi.org/10.1016/j.erss.2014.12.017

Ahmed, M. M., J.H. Sanders and W.T. Nell. 2000. New sorghum and millet cultivar introduction in Sub-Saharan Africa: impacts and research agenda Agric. Syst. 64:55–55.

Akinnagbe, O. and I.J. Irohibe. 2014. Agricultural adaptation strategies to climate change impacts in africa: a review a Bangladesh J. Agric. Res. 39 407–18 Online: https://www.banglajol.info/index.php/BJAR/article/viewFile/21984/15088.

Asumadu-sarkodie, S. and P.A. Owusu. 2016. A review of Ghana's solar energy potential AIMS Energy 4:675–96

Azongo, D.K., T. Awine, G. Wak, F.N. Binka and A.R. Oduro. 2012. A time series analysis of weather variability and all-cause mortality in the Kasena-Nankana districts of Northern Ghana, 1995-2010 Glob. Health Action 5:14–22.

Baafi, A.A. 2017. Half of food crops lost to post- harvest - Graphic Online.

Baoua, I.B., O. Bakoye, L. Amadou and L.L. Murdock. 2018. Performance of PICS bags under extreme conditions in the sahel zone of Performance of PICS bags under extreme conditions in the sahel zone of Niger. J. Stored Prod. Res. 76:96–101 Online: https://doi.org/10.1016/j.jspr.2018.01.007.

Barrett, S. 2007. Who Should Foot the Bill on Climate Change. Yale Global Online: https://yaleglobal.yale.edu/content/who-should-foot-bill-climate-change

Bayuo, B.B. 2017. Growing technology and innovation in Sub-Saharan Africa through Business Innovation Centres: Case study of (Lund University)

BNRCC. 2011. National Adaptation Strategy and Plan of Action on Climate Change for Nigeria (NASPA-CCN) Federal Ministry of Environment Special Climate Change Unit Prepared by the Online: http://csdevnet.org/wp-content/uploads/NATIONAL-ADAPTATION-STRATEGY-AND-PLAN-OF-ACTION.pdf.

Boko, M. I. Niang, A. Nyong, C. Vogel, A. Githeko, M. Medany, B. Osman-Elasha, R. Tabo and P. Yanda. 2008. Africa, Climate change 2007: Impacts, adaptation and vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change ed P J van der L and C E H M.L. Parry, O.F. Canziani, J.P. Palutikof (Cambridge UK: Cambridge University Press) pp 433–67 Online: https://cgspace.cgiar.org/handle/10568/17019.

CBI Market Intelligence. 2016. CBI Trade Statistics: Cocoa in Europe Online: https://www.cbi.eu/sites/default/files/market_information/researches/trade-statistics-europe-cocoa-2016.pdf.

Compassion in the World Farming.2013. Statistics: Laying hens 1–10 Online: https://www.ciwf.org.uk/media/5235021/Statistics-Laying-hens.pdf.

Creech, H., B. Akoh and J.E. Parry. 2012. ICTs for Climate change adaptation in Africa.

Dinesh, D. and S. Vermeulen. 2016. Climate change adaptation in agriculture: practices and technologies - Opportunities for climate action in agricultural systems 1–7 Online: https://cgspace.cgiar.org/handle/10568/71053.

Eder, J.M., C.F. Mutsaerts and P. Sriwannawit. 2015. Mini-grids and renewable energy in rural Africa : How diffusion theory explains adoption of electricity in Uganda Energy Res. Soc. Sci. 5:45–54.

Elbehri, A., J. Kaminski, S. Koroma, M. Iafrate, M. Division and M. Division. 2013. West Africa food systems: An overview of trends and indicators of demand, supply, and competitiveness of staple food value chains Rebuilding West Africa's Food Potential ed A Elbehri (FAO/IFAD) pp.1–42.

Ergano, K. 2017. Interdependencies and sequential patterns in adoption of dairy technologies in Ethiopia J. Dev. Agric. Econ. 9:200–9.

FAO. 2018. Animal production FAO's role Anim. Prod. Online: http://www.fao.org/animal-production/en/

Fatunbi, O. and R. Odogola. 2018. Status of Smallholders Agricultural Mechanization in Sub-Saharan Africa FARA Res. Reports 2.

Frempon-Ntiamoah, E. 2018. US $25m Cassava Starch Processing Factory to Be Established in Nkwanta South Gov. Ghana Online: http://www.ghana.gov.gh/index.php/media-center/news/4753-us-25m-cassava-starch-processing-factory-to-be-established-in-nkwanta-south.

Goddek, S., B. Delaide, U. Mankasingh, K.V. Ragnarsdottir, H. Jijakli and R. Thorarinsdottir. 2015. Challenges of Sustainable and Commercial Aquaponics Sustainability 7:4199–224.

Hancock, K.J. 2015. The expanding horizon of renewable energy in sub-Saharan Africa: Leading research in the social sciences & Energy Res. Soc. Sci. 5:1–8 Online: http://dx.doi.org/10.1016/j.erss.2014.12.021.

Heise, H., A. Crisan and L. Theuvsen. 2015. The Poultry Market in Nigeria: Market Structures and Potential for Investment in the Market Int. Food Agribus. Manag. 18:197–222.

Herrero, M., P. Havlik, J. McIntire, A. Palazzo and H. Valin. 2014. African Livestock Futures: Realizing the potential of livestock for food security, poverty reduction and the environment in Sub-Saharan Africa (Geneva, Switzerland).

Housseini, B. and S. Alkire. 2014. Multidimensional Poverty in Sub-Saharan Africa: Levels and Trends Online: http://www.ophi.org.uk.

IMF. 2017. Sub-Saharan Africa: Restarting the growth engine (International Monetary Fund, Publication Services) Online: www.elibrary.imf.org

IMF. 2018. World Economic Outlook - Google Public Data Explorer Google Online: https://www.google.com/publicdata/explore?ds=k3s92bru78li6_#!ctype=l&strail=false&bcs=d&nselm=h&met_y=ngdp_rpch&scale_y=lin&ind_y=false&rdim=world&idim=country:IN&ifdim=world&hl=en_US&dl=en_US&ind=false.

Imran, M., N. Maqbool and H. Shafique. 2014. Impact of Technological Advancement on Employee Performance in Banking Sector Int. J. Hum. Resour. Stud. 4 57 Online: http://www.macrothink.org/journal/index.php/ijhrs/article/view/5229.

Kambou, G. 2018. Sub-Saharan Africa Global Economic Prospects pp 137–56 Online: http://mdm.sagepub.com/cgi/doi/10.1177/027298901220624 15.

Kaneda, T. and G. Dupuis. 2017. 2017 World Population Data Sheet: With A Special Focus on Youth Online: http://www.prb.org/Publications/Datasheets/2016/2016-world-population-data-sheet.aspx.

Kim, D., A.D. Thomas, D. Pelster, T.S. Rosenstock and A. Sanz-cobena. 2016. Greenhouse gas emissions from natural ecosystems and agricultural lands in sub-Saharan Africa: synthesis of available data and suggestions for further research Biogeosciences 13 4789–809 Online: https://www.biogeosciences.net/13/4789/2016/bg-13-4789-2016.pdf.

Kitinoja, L. 2013. Innovative Small-scale Postharvest Technologies for reducing losses in Horticultural Crops Ethiop. J. Appl. Sci. Technol. Special Is 9–15 Online: http://ucce.ucdavis.edu/files/datastore/234-2584.pdf.

Magnusson, U. 2016. Sustainable global livestock development for food security and nutrition including roles for Sweden Online: https://www.slu.se/globalassets/ew/org/andra-enh/uadm/global/pdf/rapport_fao_livestock-tillg_webbsan.pdf.

Masinde, M. 2015. An innovative drought early warning system for sub-saharan Africa: Integrating modern and indigenous approaches African J. Sci. Technol. Innov. Dev. 7:8–25.

Ministry of Environment and Fishery Resources. 2015. Burkina Faso National Climate Change Adaptation Plan (NAP) Online: http://www4.unfccc.int/nap/Documents/Parties/PNA_Version_version finale[Transmission].pdf

Ministry of Natural Resources. 2012. Republic of Rwanda Technology Needs Assessment and Technology Action Plans For Climate Change Mitigation and Adaptation Online: http://www.rema.gov.rw/fileadmin/templates/Documents/rema_doc/CC depart/TNA_Final report.pdf

Mmaduabuchukwu, M. 2013. Some Indicators of African Agriculture Situations, Exports and Opportunities J. Bus. Adm. Educ. 3:123–55.

Mohammed, Y.S., M.W. Mustafa and N. Bashir. 2013. Status of renewable energy consumption and developmental challenges in Sub-Sahara Africa Renew. Sustain. Energy Rev. 27:453–63 Online: http://dx.doi.org/10.1016/j.rser.2013.06.044.

Morris, D. 2013. Who Should Pay Climate Change Costs_ - Our World Online: https://ourworld.unu.edu/en/who-should-pay-climate-change-costs.

Mwai, O.A. and J.M.K. Ojango. 2016. Livestock production in Sub-Saharan Africa: Prospects for exploiting resilient livestock genotypes in the light of climate change

Mwai, O., O. Hanotte, Y. Kwon and S. Cho. 2015. African Indigenous Cattle: Unique Genetic Resources in a Rapidly Changing World Asian-Australasian J. Anim. Sci. 28 911–21 Online: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4478499/pdf/ajas-28-7-911.pdf

National Agricultural Statistics Service. 2017. Milk Production.

National TNA Project. 2013. The Republic of Sudan Technology Needs Assessment for Climate Change Adaptation January-2013 (Khartoum, Sudan) Online: http://www.tech-action.org/-/media/Sites/TNA_project/TNA Reports Phase 1/Africa and Middle East/Sudan/TechnologyNeedsAssessmentClimateChangeAdptation_Sudan.ashx?la=da

Nation Master. 2018. Sub-Saharan Africa: Statistical Profile Online: https://www.google.com/publicdata/explore?ds=d5bncppjof8f9_#!ctype=l&strail=false&bcs=d&nselm=h&met_y=sp_pop_grow&scale_y=lin&ind_y=false&rdim=region&idim=region:SSF&idim=country:NGA:GHA:CIV:ETH:KEN&ifdim=region&tstart=966805200000&tend=1408568400000&hl=e

Niang, I., O.C. Ruppel, M.A. Abdrabo, A. Essel, C. Lennard, J. Padgham and P. Urquhart. 2014. Africa Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change ed V.R. Barros, C.B. Field, D.J. Dokken, M.D. Mastrandrea, K.J. Mach, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea and L.L. White (Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press) pp.1199–265.

Nzuma, J.M., M. Waithaka, R.M. Mulwa, M. Kyotalimye and G. Nelson. 2010. Strategies for Adapting to Climate Change in Rural Sub-Saharan Africa A Review of Data Sources, Poverty Reduction Strategy Programs (PRSPs) and National Adaptation Plans for Agriculture (NAPAs) in ASARECA Member Countries vol 1013 Online: http://www.eis-africa.org/EIS-Africa/2ifpri_review.pdf.

OECD/FAO. 2016. Agriculture in Sub-Saharan Africa : Prospects and challenges for the next decade OECD-FAO Agricultural Outlook 2016-2025 vol 181 (Paris) pp 59–95 Online: http://www.fao.org/3/a-BO092E.pdf.

Rewe, T.O., P. Herold, A.K. Kahi and A.V. Zárate. 2009. Breeding indigenous cattle genetic resources for beef production in Sub-Saharan Africa Outlook Agric. 38 317–26.

Rivera-Santos, M., D. Holt, D. Littlewood and A. Kolk. 2015. Social Entrepreneurship in Sub-Saharan Africa Acad. Manag. Perspect. 29:72–91.

Saghir, J. 2015. Confronting Drought in Africa ' s Drylands Opportunities for Enhancing Resilience: Findings and

recommendations of a major new study The Sahel & West Africa Week, EXPO.

Serdeczny, O., S. Adams, F. Baarsch, D. Coumou, A. Robinson, W. Hare, M. Schaeffer and M. Perrette. 2016. Climate change impacts in Sub-Saharan Africa: from physical changes to their social repercussions Reg. Environ. Chang.PP.15.

Smutka, L. and K. Tomšík. 2011. Selected aspects of GDP value and structure development in sub-Saharan Africa Acta Univ. Agric. Silvic. Mendelianae Brun. 59:347–62

Strydom, P.E. 2008. Do indigenous Southern African cattle breeds have the right genetics for commercial production of quality meat ? Meat Sci. 80:86–93.

The National Academy of Sciences. 2008. Emerging Technologies to Benefit Farmers in Sub-Saharan Africa and South Asia (Washington, D.C.) Online: http://nas-sites.org/ag-technologies/files/2012/12/52606862-Farmers-in-Sub-Saharan-Africa-and-South-Asia-Report-in-Brief.pdf.

The Rock Foundation. 2015. Perspectives to Reducing Post-harvest Losses of Agricultural Products in Africa Online: https://www.afdb.org/fileadmin/uploads/afdb/Documents/Events/DakAgri2015/Agriculture_Industrialization_and_post-harvest_losses.pdf.

Trabucco, A. and R. Zomer. 2014. Influence of Aridity on Vegetation Online: http://ebrary.ifpri.org/cdm/singleitem/collection/p15738coll2/id/128169/rec/1.

UNFCCC. Conference of the Parties (COP). 2015. Durban Platform for Enhanced Action (decision 1/CP.17) Adoption of a protocol, another legal instrument, or an agreed outcome with legal force under the Convention applicable to all Parties Adoption of the Paris Agreement. Proposal by the President.21932 pp. 32 Online: http://unfccc.int/resource/docs/2015/cop21/eng/l09r01.pdf.

UNFCCC. 2006. Technologies For Adaptation To Climate Change Online: http://www.tandfonline.com/doi/abs/10.3763/cdev.2010.0064%5Cnhttp://nfccc.int/ttclear/pdf/tech_for_adaptation.pdf%5Cnpapers://244e4fe4-576c-4ea5-8610-2950d666e3ec/Paper/p205%5Cnhttp://www.odi.org.uk/work/themes/details.asp?id=313&title=adaptation-climate-change.

United Nations. 2009. Trends İn Sustainable Development: Africa Report 2008-2009 (New York) Online: https://sustainabledevelopment.un.org/content/documents/fullreport.pdf.

USAID. 2011. Climate Change Adaptation in WESTERN AFRICA Online: https://www.climatelinks.org/file/685/download?token=ftVT_EFJ.Williams S.B., L.L. Murdock and D. Baributsa. 2017. Storage of Maize in Purdue Improved Crop Storage (PICS) Bags PLoS One.12:1–12.

World Bank. 2011. Global Economic Prospects: Maintaining Progress amid Turmoil vol 3Incomplete.

World Bank. 2018a. Agricultural land World Dev. Indic. - Google Public Data Explor. Online: https://www.google.com/publicdata/explore?ds=d5bncppjof8f9_&ctype=l&met_y=agricultural_production_index#!ctype=l&strail=false&bcs=d&nselm=h&met_y=ag_lnd_agri_k2&scale_y=lin&ind_y=false&rdim=region&idim=region:SSF:ECS:NAC:SAS:EAS&ifdim=region&tdim=true&tst.

World Bank. 2018b. Cereal Production World Dev. Indic. - Google Public Data Explor. Online: https://www.google.com/publicdata/explore?ds=d5bncppjof8f9_&ctype=l&met_y=ag_yld_crel_kg#!ctype=l&strail=false&bcs=d&nselm=h&met_y=ag_prd_crel_mt&scale_y=lin&ind_y=false&rdim=region&idim=region:SSF:NAC:ECS:SAS:MEA:EAS:LCN&ifdim=region&tdim=true&tstart=134.

World Bank. 2018c. CO2 emissions per capita World Dev. Indic. - Google Public Data Explor. Emiss. Online: https://www.google.com/publicdata/explore?ds=d5bncppjof8f9_#!ctype=l&strail=false&bcs=d&nselm=h&met_y=en_atm_co2e_pc&scale_y=lin&ind_y=false&rdim=region&idim=region:ECS:SSF:NAC:MEA:LCN:EAS:SAS&ifdim=region&tdim=true&tstart=1124571600000&tend=1408568400000.

World Bank. 2018d. Energy Use per Capita World Dev. Indic. - Google Public Data Explor. Online: https://www.google.com/publicdata/explore?ds=d5bncppjof8f9_#!ctype=l&strail=false&bcs=d&nselm=h&met_y=eg_use_pcap_kg_oe&scale_y=lin&ind_y=false&rdim=region&idim=region:SSF:NAC&ifdim=region&tdim=true&hl=en_US&dl=en_US&ind=false.

World Bank. 2018e. Fertilizer Consumption World Dev. Indic. - Google Public Data Explor. Online: https://www.google.com/publicdata/explore?ds=d5bncppjof8f9_&ctype=l&met_y=agricultural_production_index#!ctype=l&strail=false&bcs=d&nselm=h&met_y=ag_con_fert_zs&scale_y=lin&ind_y=false&rdim=region&idim=region:ECS:NAC:SSF:SAS:MEA:LCN:EAS&ifdim=region&tdim=

World Bank. 2018f. Population Growth Rate World Dev. Indic. - Google Public Data Explor. Online: https://www.google.com/publicdata/explore?ds=d5bncppjof8f9_#!ctype=l&strail=false&bcs=d&nselm=h&met_y=sp_pop_grow&scale_y=lin&ind_y=false&rdim=region&idim=region:SSF&idim=country:NGA:GHA:CIV:ETH:KEN&ifdim=region&tstart=966805200000&tend=1408568400000&hl=e.